Angela Mincemoyer
Structural Option
Advisor: Dr. Boothby
Peggy Ryan Williams Center
Ithaca, New York
27 September 2013

Peggy Ryan Williams Center

Technical Report 2

Angela Mincemoyer
Structural Option
September 27, 2013

Dr. Boothby
Advisor
Penn State University

Dear Dr. Boothby,

The following Technical Report 2 was prepared for AE 481W. Gravity loads (including both dead loads and live loads), snow loads, wind loads, and seismic loads were calculated for the Peggy Ryan Williams Center as part of this report. Various hand calculations and an Excel sheet detail all of these load calculations and results.

Thank you in advance for taking the time to review the following report.

Sincerely,

Angela Mincemoyer

Enclosed: Technical Report 2

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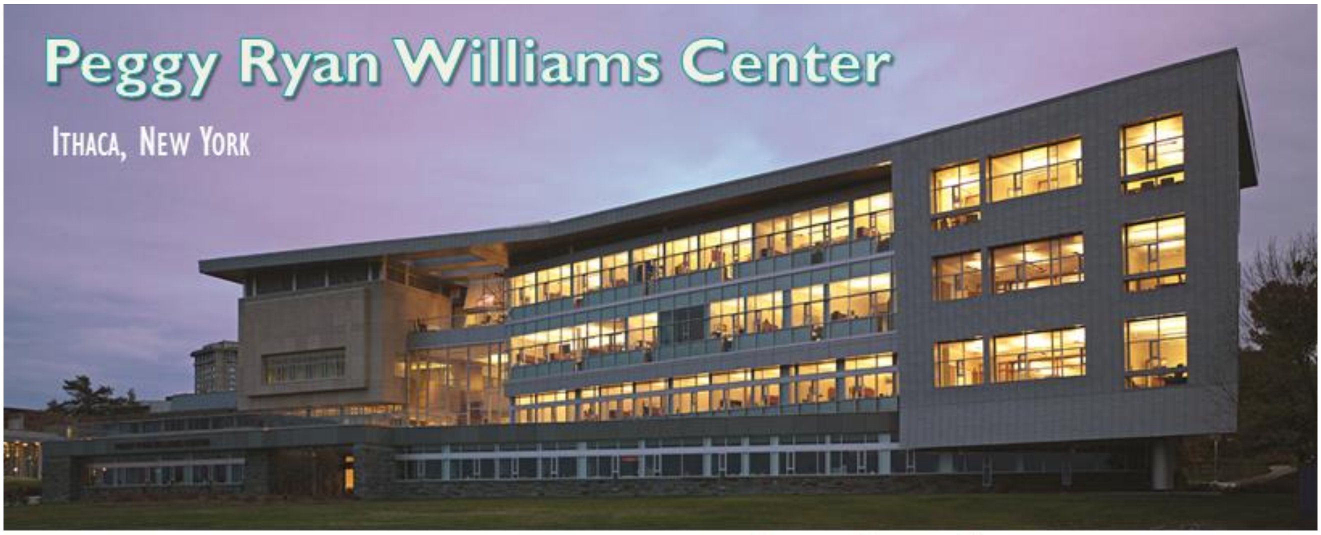


Peggy Ryan Williams Center

Ithaca, New York

Primary Project Team:

Owner | Ithaca College

Architect | Holt Architects

Structural Engineer | Ryan-Biggs Associates

Mechanical & Electrical Engineer | Delta Engineers

General Contractor | Christa Construction

Architecture:

- Various aspects were driven by desire to be eco-friendly
- Large areas of glass provide breath-taking views of Cayuga Lake
- Façade consists of zinc panels, blue stone veneer, composite aluminum panels, and limestone panels
- Pedestrian bridge connects PRWC to adjacent building

Sustainability:

- Awarded LEED Platinum
- "V" shaped roof aids in rain water collection
- Day lighting made possible by large areas of glass
- Intensive Green Roof
- Atrium promotes natural ventilation

Structure:

- *Foundation*
  - Slab-on-grade, foundation walls, footings, various grade beams, piers and drilled piers
- *Framing System*
  - All floors are composed of composite steel decking
  - Steel framing consists of wide flange beams, girders, and columns
- *Lateral System*
  - Concentrically braced structural steel frames in both the North-South and East-West directions

General Building Data:

Building Occupant | Ithaca College

Occupancy | Office Use

Size | 58,200 square feet

Stories | 4 stories above grade

Substantial Completion | March 2010

Cost of Construction | approx. $19.3 million

Project Delivery Method | Design-Bid-Build

MEP:

- *Mechanical*
  - Main heating and cooling source is geothermal via a closed loop system adjacent to the building
  - Two dedicated outdoor air units (DOA) will utilize water to water heat pumps
- *Electrical*
  - Primary Service: 12.5 KV primary fused switches, 500 KVA transformer, 480/277 Volt Distribution Switchboard
  - Secondary Distribution: 150 KVA, 480V to 120/208 Volt transformer and (1) 120/208 Volt Main power panel
- *Plumbing*
  - Collect and store rainwater for gray water use
  - (3) rainwater collections tanks

Angela Mincemoyer | Structural | http://www.engr.psu.edu/ae/thesis/portfolios/2014/ahm5066/index.html

Executive Summary

The Peggy Ryan Williams Center, formerly known as "The Gateway Building," is a four story office building located on the Ithaca College campus, Ithaca, New York. The building was originally known as "The Gateway Building" because the college saw the building as a gateway to the campus. At the time, the college was moving into a new era of sustainability and they wanted to show their prospective students, employees, and visitors the strides that they were making towards their goal.

Sustainability and a desire to connect with nature were both driving forces for the building's architectural features. The large areas of glass, offering vistas to Cayuga Lake, allow the occupants to feel like they are part of the nature around them. Other eco-friendly architectural features include the "V" shaped roof which aids in rainwater collection, and the large atrium which extends through the building to promote natural ventilation.

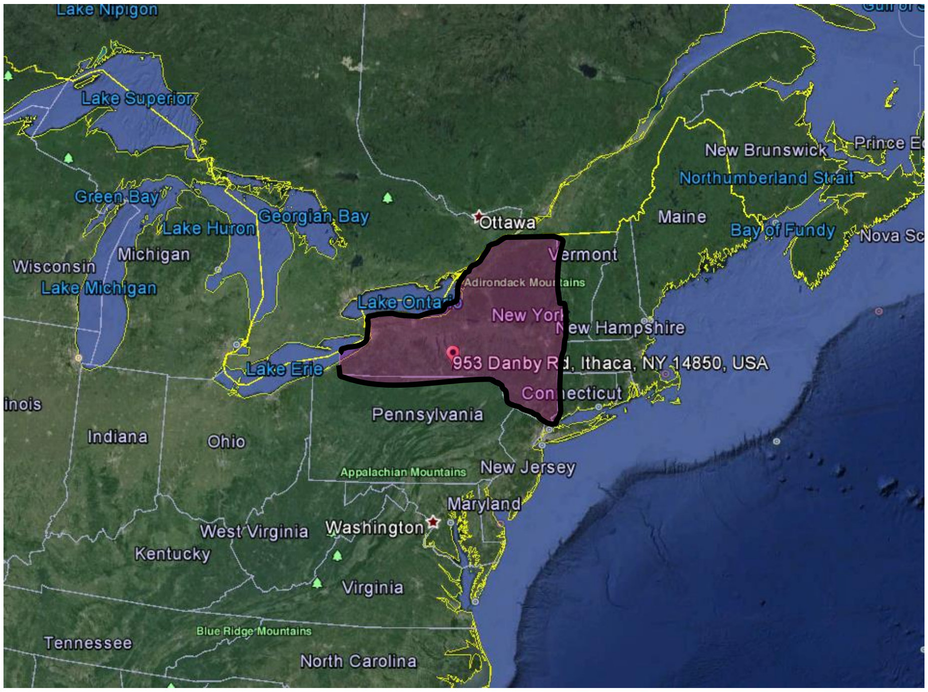
The structural system components are fairly common; however, their placement and size variations make the framing very irregular. The roof of the building is constructed of roof decking, which spans perpendicular to the beams, girders, and columns. The floor of Level 1 through Level 3 consists of composite decking and wide flanged beams, girders, and columns. Various beams and girders are provided with shear studs for composite action. Sizes and spans of the wide flanges vary greatly throughout the building and even throughout a single floor framing system. At locations where the building cantilevers, moment connections and larger beam/girder sizes make the cantilevers possible.

Columns, piers, and drilled piers support the foundation for the PRWC. The drilled piers range from resting on top of bedrock, to being drilled down 4'-0" below competent bedrock, depending on their location and loading.

Another distinctive feature of the Peggy Ryan Williams Center is the pedestrian bridge, which connects the building to the adjacent Dillingham Center. The bridge is a box truss supported in a double cantilever configuration with a 2" expansion joint on either end. I am eager to explore ways to improve the existing design for the bridge.

Due to its location, the PRWC was designed following the 2002 Building Code of New York State (BCNYS) which adopted the 2000 International Building Code (IBC). In addition to the BCNYS, additional loading and design requirements from American Society of Civil Engineering (ASCE) 7-98 are incorporated by reference into the IBC. In addition, various other codes were used in the design and are discussed in further detail in the following report.

Site Plan and Location Plan



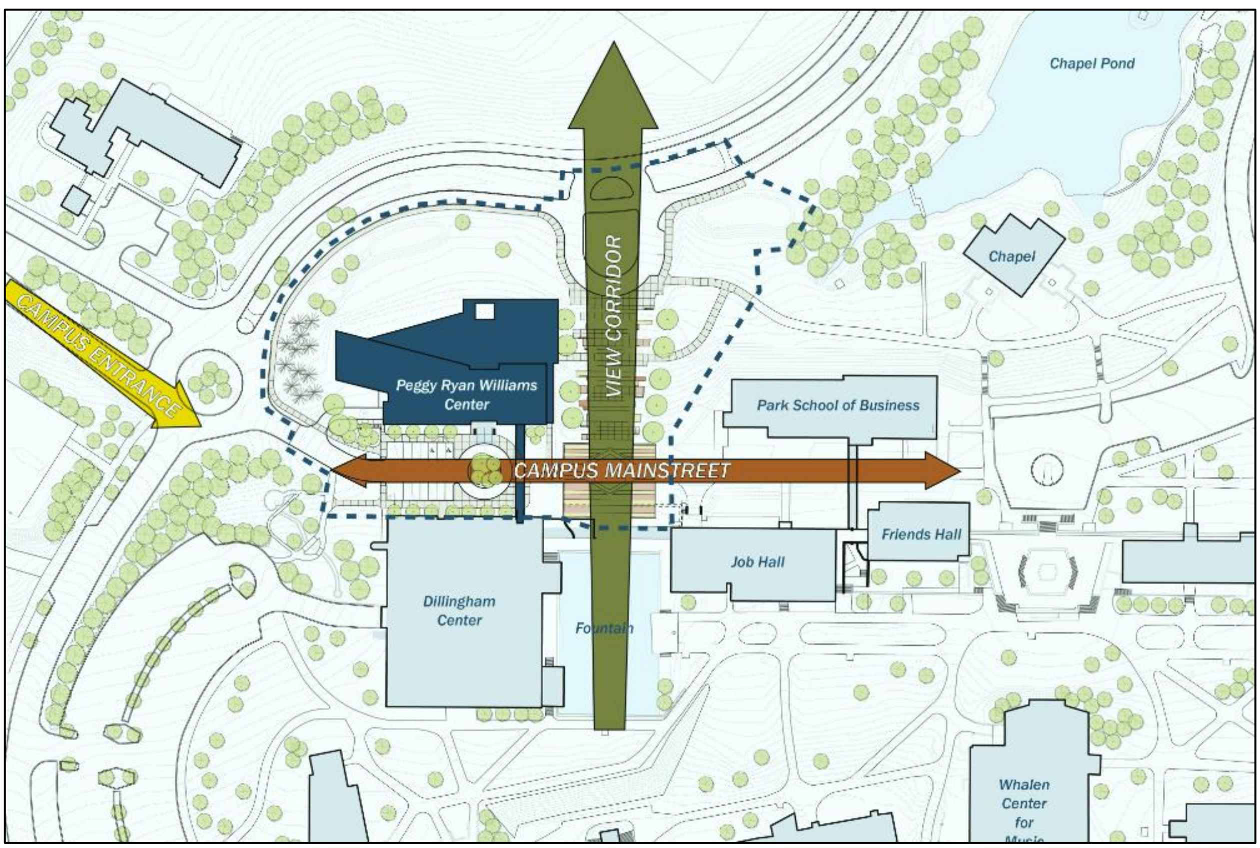


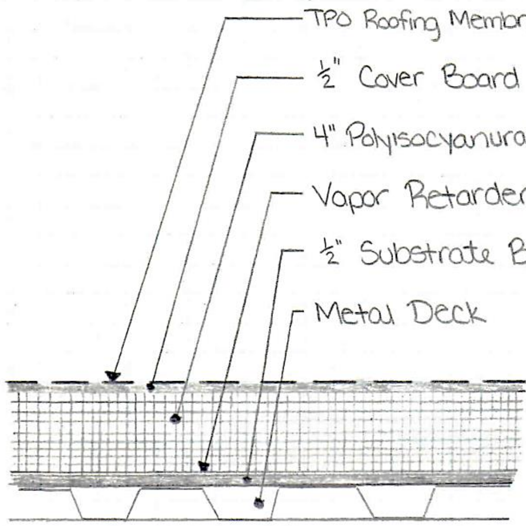
Photo provided courtesy of Holt Architects

Documents Used in Preparation of this Report

- Building Code of New York State
  - 2002 BCNYS (IBC 2000 adopted)
- American Society of Civil Engineers
  - ASCE 7-98: Minimum Design Loads for Buildings and Other Structures
- Vulcraft Deck Catalog

TYPICAL ROOF BAY LOADING

Sketch of detail H5 Membrane Roofing RS-1 page A001



DEAD LOADS:

TPO Roofing membrane, adhered = 2 psf

½" cover board = 2 psf

4" Polyisocyanurate insulation = 6 psf

Vapor retarder = 1 psf

½" substrate board = 2 psf

Metal deck = 2.2 psf

Misc. & Superimposed:

mechanical equipment & piping = 5 psf
sprinklers = 10 psf
lighting = 5 psf
suspended ceiling = 3 psf
framing allowance = 10 psf

→ Total roof dead load = 48.2 psf

(25 psf roof dead load was used in design)

LIVE LOADS:

per ASCE7-98 section 4.9 Minimum Roof Live Loads required the use of equation 4-2 ($L_r = 20R_1R_2$, where $12 \le L_r \le 20$).
The variable R_1 & R_2 rely on tributary areas. Because I am looking for a typical psf (I do not have a tributary area) I will be conservative and set $L_r = 20$ psf.

(ASCE7-98) roof live load = 20 psf

- No design roof live load was provided
  → roof snow load most likey controlled

SNOW LOADS:

uniform ground snow load (p_g) = 45 psf

$p_f = 0.7\,C_eC_tIp_g$

min $p_f = 20 \cdot I$

Exposure Factor (C_e) = 1.0
- partially exposed
- exposure B

Thermal Factor (C_t) = 1.0

Importance Factor (I) = 1.1
- category III

→ $p_f = 0.7(1.0)(1.0)(1.1)(45) = 34.65$ psf

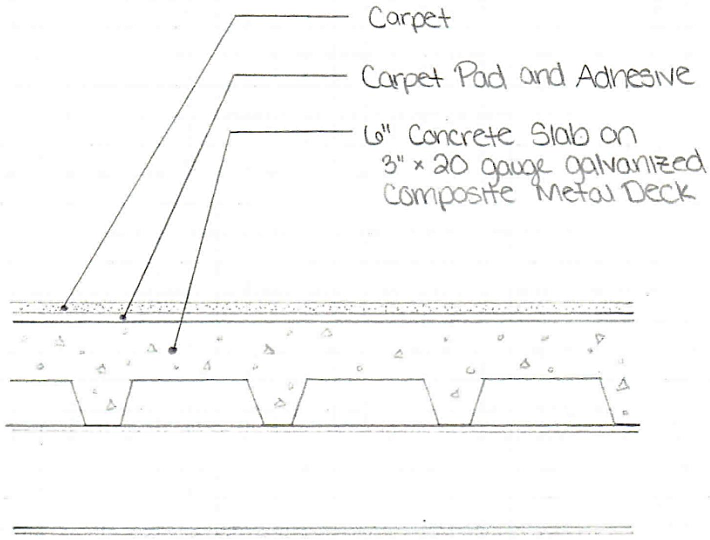
check min p_f:
min $p_f = 20 \cdot I = 20(1.1) = 22$ psf < 34.65 psf ✓

→ $p_f = 35$ psf

→ design uniform flat-roof snow load = 35 psf

→ the design matches the code minimum

TYPICAL FLOOR BAY LOADING:



DEAD LOADS:

Carpet = 1 psf

carpet pad & adhesive = 1.5 psf

6" concrete slab on 3" × 20 gauge galvanized composite metal Deck = 57 psf

Misc & Superimposed:

mechanical equipment & piping = 5 psf
sprinklers = 10 psf
lighting = 5 psf
suspended ceiling = 3 psf
framing allowance = 10 psf

→ Total floor dead load = 92.5 psf

(for interior floors, a 80 psf dead load was used in design)

Angela Mincemoyer	Gravity Loads	Tech Report 2	10/43

LIVE LOADS:

Live load = 80 psf

(corridors above first floor used for flexibility)

→ design interior floor live load = 80 psf

→ the design matches the code minimum

NON-TYPICAL LOADS:

Green Roof: (detail H7 - roof type RS-2)

DEAD LOADS: vegetation & planting medium = 70 psf

water retention composite = 2 psf

moisture mat = 2 psf

4" extruded polystyrene insulation = 1 psf

drainage composite = 2 psf

root barrier = 2 psf

hot fluid applied roofing = 2 psf

6" concrete slab on 3" × 20 ga galvanized composite metal deck = 57 psf (pg. 54 of Vulcraft catalog)

misc & superimposed:

same as typical roof bay = 33 psf

Total Roof Dead Load = 171 psf

(Design dead load = 120 psf)

LIVE LOADS: **Live Load = 100 psf** (ASCE 7-98)

(Design live load = 100 psf)

Roof System RS-3 : used on first floor roof (deck area)

DEAD LOADS:

2" bluestone paver = 26 psf
→ per Bluestone Guide from Braen Supply Inc)

pedestal system = 3 psf

4" extruded polystyrene insulation = 1 psf

drainage composite = 2 psf

hot liquid applied roofing = 2 psf

6" concrete slab on 3" × 20 ga galvanized composite metal deck = 57 psf (pg. 54 of Vulcraft catalog)

misc & superimposed:

same as typical roof bay = 33 psf

Total Roof Dead Load = 124 psf

(Design dead load = 120 psf)

LIVE LOADS:

Live Load = 100 psf (ASCE 7-98)

(Design live load = 100 psf)

Misc. Floors:

first floor:

DEAD LOAD: 7" concrete slab on 3" × 20 ga. galvanized composite metal deck = 69 psf (pg. 54 of Vulcraft catalog)

* this composite deck weighs 12 psf more than the typical floor bay loading.

→ For areas of 7" concrete slab on 3" × 20 ga. galvanized composite metal deck, an addition 12 psf should be added to the typical floor bay loading.

→ This will result in a total dead load = 104.5 psf

(Design dead load = 80 psf)

Interior floor with Bluestone:

DEAD LOAD: 2" bluestone paver = 26 psf
→ per Bluestone Guide from Braen Supply, Inc)

pedestal system = 3 psf

in addition to typical floor bay loading = 90 psf
(carpet, carpet pad & adhesive are not included in this load)

Total floor dead load = 119 psf

(design dead load = 120 psf)

LIVE LOAD: In areas where bluestone flooring is present, an additional 20 psf live live should be added to the typical floor bay live load. Resulting in a total floor live load of 100 psf in those areas.

The additional 20 psf is added to account for any repairs that may be required in the future, such as broken/cracked sections needing to be replaced.

(design live load = 100 psf)

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Mechanical Room:

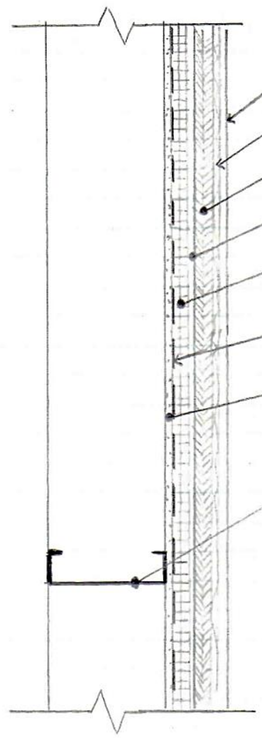
Live load = 150 psf

(industry standard)

Stairs:

Live load = 100 psf (ASCE7-98)

TYPICAL EXTERIOR WALL DETAIL: Zinc Panels (EW-4)



DEAD LOADS:

Flat Lock Zinc Panel = 2 psf
Separation sheet = 1 psf
3/4" Plywood Sheathing = 2.4 psf (ASCE 7-10)
3/4" Extruded Polystyrene Insulation = 0.5 psf
Weather Barrier = 1 psf
1/2" gypsum sheathing = 2 psf (ASCE 7-10)
6" metal studs @ 16" o.c. = 4 psf
Spray foam insulation = 1 psf

Total dead load = 13.9 psf

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LOAD PATH DESCRIPTION:

The exterior wall facade load is carried by a grid of 6" metal studs @ 16" O.C. The load is first transferred to the horizontal 6" metal studs and then into the vertical 6" metal studs. The metal studs then transfer the load into the foundation.

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First Floor Roof - North Side - Green Roof & Plaza Deck:

Determine if drift load is required: (section 7.7.1)

$h_c/h_b < 0.2 \Rightarrow$ not required

$\gamma = 0.13 p_g + 14 < 30$ pcf
$= 0.13(45) + 14 = 19.85$ pcf < 30 ✓

$h_b = \frac{p_f}{\gamma} = \frac{35}{19.85} \rightarrow h_b = 1.76'$

$h_c = 45' - 1.76' = 43.24'$

$\frac{h_c}{h_b} = \frac{43.24}{1.76} = 24.6 \rightarrow$ drift is required

Leeward: (Fig. 7-9)

$h_d = 0.43 \sqrt[3]{l_u} \sqrt[4]{p_g + 10} - 1.5$

$l_u = 98'$

$= 0.43 \sqrt[3]{98} \sqrt[4]{45+10} - 1.5$

$h_d = 3.90$ ft

Windward: (Fig. 7-9)

$l_u = 20$ ft

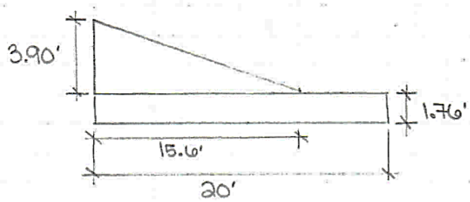
$h_d = (0.43 \sqrt[3]{20} \sqrt[4]{45+10} - 1.5) \, 3/4$

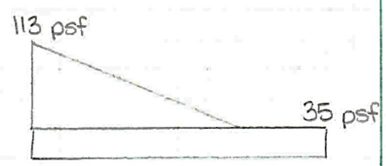
$h_d = 1.26$ ft

$\rightarrow h_d = 3.90$ ft should be used in design

$h_d < h_c \rightarrow \quad w = 4h_d = 4(3.90) = 15.6$ ft

$h_d \gamma = 3.90'(19.85) = 78$ psf





First Floor Roof - East Side - Plaza Deck:

Determine if drift load is required: (section 7.7.1)

$h_c/h_b < 0.2 \Rightarrow$ not required

$\gamma = 19.85$ pcf (see calculation on previous page)

$h_b = 1.76'$ (see calculation on previous page)

$h_c = 47' - 1.76' = 45.24'$

$\frac{h_c}{h_b} = \frac{45.24}{1.76} = 25.7 \rightarrow$ drift is required

Leeward: (Fig. 7-9)

$h_d = 0.43 \sqrt[3]{l_u} \sqrt[4]{p_g + 10} - 1.5$

$l_u = 237'$

$h_d = 0.43 \sqrt[3]{237} \sqrt[4]{45+10} - 1.5$

$h_d = 5.75'$

Windward:

$$l_u = 14.5'$$

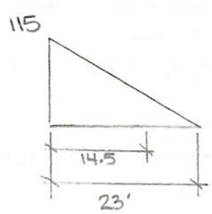
$$h_d = (0.43 \sqrt[3]{14.5} \sqrt[4]{45+10} - 1.5)\, 3/4$$

$$h_d = 1.02'$$

$\rightarrow h_d = 5.75$ ft should be used in design

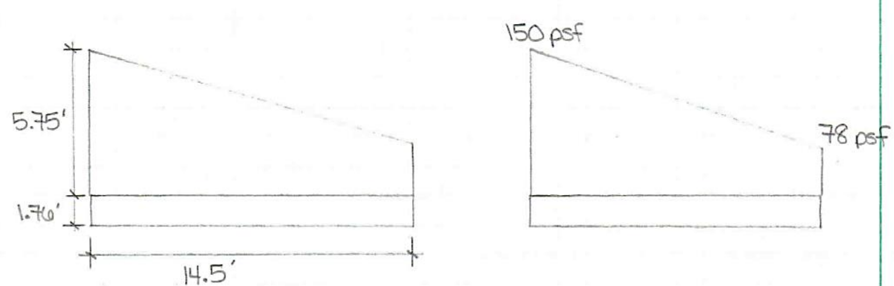
$h_d < h_c \rightarrow w = 4h_d = 4(5.75) = 23$ ft

$$h_d \gamma = 5.75(19.85) = 115 \text{ psf}$$



$$\frac{115}{23} = \frac{x}{23-14.5}$$

$$x = 43 \text{ psf}$$



Per ASCE7-98 Chapter 6:

METHOD 1: BCNYS Section 1609.6

- according to IBC2000 section 1609.6, the mean roof height must not exceed the least horizontal dimension, in order to use the simplified method
  - → least horizontal dimension ≈ 29 ft
  - → mean roof height > 29 ft

⇒ Method 1 (simplified method) may not be used

METHOD 3:

- wind tunnel tests must be completed in order to determine design wind loads

⇒ Method 3 is not feasible for this report

METHOD 2:

- I will use this method to calculate the wind loads on the Peggy Ryan Williams Center.

(assuming no irregular geometries)

ASCE7-98: Section 6.5.3 - Design Procedure

Steps:

#1

Basic Wind speed, V (Per Fig 6-1) → V = 90 mph

Wind directionality factor, Kd

→ Buildings → Main Wind Force Resisting System (Per table 6-6) → Kd = 0.85

#2 Importance Factor, I

per Table 1-1 → Category III
- "Buildings or other structures with a capacity greater than 500 for colleges or adult education facilities"

per Table 6-1 → I = 1.15

#3

Exposure Category

per section 6.5.6.1 → Exposure B

Velocity Pressure Exposure Coefficient

per Table 6-5:

mean roof height > least horizontal dimension → NOT a low-rise building

→ must use case 2

North-South Direction - Main Roof: (Table 6-5)

Garden Level:

$z = 4\ ft \rightarrow K_{z_G} = 0.57$

Level 1:

$z = 17.25\ ft \rightarrow K_{z_1} = 0.5925$

Level 2:

$z = 30.5\ ft \rightarrow K_{z_2} = 0.703$

Level 3:

$z = 43.75\ ft \rightarrow K_{z_3} = 0.779$

Roof:

$z = 65\ ft \rightarrow K_{z_R} = 0.87$

North-South Direction - Atrium: (Table 6-5)

Garden Level: $K_{z_G} = 0.57$

Level 1: $K_{z_1} = 0.5925$

Level 2: $K_{z_2} = 0.703$

Level 3: $K_{z_3} = 0.779$

Roof:

$z = 70\ ft \rightarrow K_{z_R} = 0.89$

East-West Direction - Main Roof: (Table 6-5)

Garden Level:

$z = 2.25$ ft → $K_{z_G} = 0.57$

Level 1:

$z = 15.5$ ft → $K_{z_1} = 0.5725$

Level 2:

$z = 28.75$ ft → $K_{z_2} = 0.69$

Level 3:

$z = 42$ ft → $K_{z_3} = 0.77$

Roof:

$z = 60$ ft → $K_{z_R} = 0.85$

East-West Direction - Atrium: (Table 6-5)

Garden Level: $K_{z_G} = 0.57$

Level 1: $K_{z_1} = 0.5725$

Level 2: $K_{z_2} = 0.69$

Level 3: $K_{z_3} = 0.77$

Roof:

$z = 67$ ft → $K_{z_R} = 0.878$

#4 Topographic Factor, K_{zt} (section 6.5.7.2)

$$K_{zt} = (1 + K_1 K_2 K_3)^2$$

→ section 6.5.7.1
H < 60 ft → $K_{zt} = 1.0$

#5 Gust Effect Factor, G

- ASCE 7-98 does not have a specific formula for the fundamental frequency
- I will estimate the fundamental frequency by setting it equal to $1/T_a$
  - where T_a = approximate fundamental period (per section 9.5.3.3)

$T_a = C_T h_n^{3/4}$ (eqn 9.5.3.3-1)

$C_T = 0.02$
$h_n = 70$ ft

$T_a = (.02)(70)^{3/4} = 0.484$

→ $n_1 = 1/T_a = \frac{1}{0.484}$ → $n_1 = 2.07$ Hz

$n_1 = 2.07$ Hz > 1.0 Hz → Rigid Building
(per 6.2 Definitions)

Section 6.5.8.1 Rigid Structures:

$$G = 0.925\left(\frac{1 + 1.7 g_Q I_{\bar{z}} Q}{1 + 1.7 g_v I_{\bar{z}}}\right) \quad \text{(eqn 6-2)}$$

$$I_{\bar{z}} = c(33/\bar{z})^{1/6} \quad \text{(eqn 6-3)}$$

$$Q = \sqrt{\frac{1}{1 + 0.63\left(\frac{B+h}{L_{\bar{z}}}\right)^{0.63}}} \quad \text{(eqn 6-4)}$$

$$L_{\bar{z}} = \ell(\bar{z}/33)^{\bar{\epsilon}} \quad \text{(eqn 6-5)}$$

North-South Direction - Main Roof :

$L_{\bar{z}} = \ell(\bar{z}/33)^{\bar{\epsilon}}$

$\bar{z} = 0.6h > z_{min}$
$= 0.6(65) = 39 > 30 ✓ \rightarrow \bar{z} = 39$

$\ell = 320$
$\bar{\epsilon} = 1/3$ } Table 6-4

$\rightarrow L_{\bar{z}} = 320\left(\frac{39}{33}\right)^{1/3} \rightarrow L_{\bar{z}} = 338.32$

$Q = \sqrt{\frac{1}{1+0.63\left(\frac{B+h}{L_{\bar{z}}}\right)^{0.63}}}$

$B = 245$ ft
$h = 65$ ft

$= \sqrt{\frac{1}{1+0.63\left(\frac{245+65}{338.32}\right)^{0.63}}} \rightarrow Q = 0.791$

$I_{\bar{z}} = c(33/\bar{z})^{1/6}$
$= (0.30)\left(33/39\right)^{1/6}$

$c = 0.30$ (Table 6-4)
$\bar{z} = 39$

$\rightarrow I_{\bar{z}} = 0.292$

$G = 0.925\left(\frac{(1+1.7g_Q I_{\bar{z}} Q)}{1+1.7g_v I_{\bar{z}}}\right)$

$g_Q = 3.4$
$g_v = 3.4$ } Section 6.5.8.1

$= 0.925\left(\frac{(1+1.7(3.4)(0.292)(0.791))}{1+1.7(3.4)(0.292)}\right)$

$\rightarrow G = 0.804$

North-South Direction- Atrium:

$L_{\bar{z}} = \ell(\bar{z}/33)^{\bar{\epsilon}}$

$\bar{z} = 0.6h > z_{min}$
$= 0.6(70) = 42 > 30$ ✓ $\rightarrow \bar{z} = 42$

$\ell = 320$, $\bar{\epsilon} = 1/3$ } Table 6-4

$\rightarrow L_{\bar{z}} = 320(42/33)^{1/3}$ $\rightarrow L_{\bar{z}} = 346.79$

$$Q = \sqrt{\frac{1}{1+0.63\left(\frac{B+h}{L_{\bar{z}}}\right)^{0.63}}}$$

$$= \sqrt{\frac{1}{1+0.63\left(\frac{245+70}{346.79}\right)^{0.63}}} \rightarrow Q = 0.792$$

$I_{\bar{z}} = c(33/\bar{z})^{1/6}$ $c = 0.30$ (Table 6-4), $\bar{z} = 42$

$= (0.30)(33/42)^{1/6}$

$\rightarrow I_{\bar{z}} = 0.288$

$$G = 0.925\left(\frac{(1+1.7g_Q I_{\bar{z}} Q)}{1+1.7g_v I_{\bar{z}}}\right)$$

$g_Q = 3.4$, $g_v = 3.4$ } section 6.5.8.1

$$= 0.925\left(\frac{(1+1.7(3.4)(.288)(.792))}{1+1.7(3.4)(.288)}\right)$$

$\rightarrow G = 0.805$

East-West Direction - Main Roof:

$L_{\bar{z}} = \ell(\bar{z}/33)^{\bar{\epsilon}}$

$\bar{z} = 0.6h > z_{min}$
$= 0.6(60) = 36 > 30$ ✓ $\rightarrow \bar{z} = 36$

$\ell = 320$, $\bar{\epsilon} = 1/3$ } Table 6-4

$\rightarrow L_{\bar{z}} = 320(36/33)^{1/3}$ $\rightarrow L_{\bar{z}} = 329.42$

$$Q = \sqrt{\frac{1}{1+0.63\left(\frac{B+h}{L_{\bar{z}}}\right)^{0.63}}}$$

$$= \sqrt{\frac{1}{1+0.63\left(\frac{110+60}{329.42}\right)^{0.63}}} \rightarrow Q = 0.841$$

$I_{\bar{z}} = c(33/\bar{z})^{1/6}$ $c = 0.30$ (Table 6-4), $\bar{z} = 36$

$= (0.30)(33/36)^{1/6}$

$\rightarrow I_{\bar{z}} = 0.296$

$$G = 0.925\left(\frac{(1+1.7g_Q I_{\bar{z}} Q)}{1+1.7g_v I_{\bar{z}}}\right)$$

$g_Q = 3.4$, $g_v = 3.4$ } section 6.5.8.1

$$= 0.925\left(\frac{(1+1.7(3.4)(.296)(.841))}{1+1.7(3.4)(.296)}\right)$$

$\rightarrow G = 0.832$

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East - West Direction - Atrium:

$$L_{\bar{z}} = \ell(\bar{z}/33)^{\bar{\epsilon}}$$

$$\bar{z} = 0.6h > z_{min}$$
$$= 0.6(67) = 40.2 > 30 \checkmark \quad \rightarrow \bar{z} = 40.2$$

$\ell = 320$, $\bar{\epsilon} = 1/3$ } Table 6-4

$$\rightarrow L_{\bar{z}} = 320(40.2/33)^{1/3} \quad \rightarrow L_{\bar{z}} = 341.76$$

$$Q = \sqrt{\frac{1}{1+0.63\left(\frac{B+h}{L_{\bar{z}}}\right)^{0.63}}}$$

$$= \sqrt{\frac{1}{1+0.63\left(\frac{110+67}{341.76}\right)^{0.63}}} \quad \rightarrow Q = 0.840$$

$$I_{\bar{z}} = c(33/\bar{z})^{1/6}$$

$c = 0.30$ (Table 6-4), $\bar{z} = 40.2$

$$= (0.30)(33/40.2)^{1/6}$$

$$\rightarrow I_{\bar{z}} = 0.290$$

$$G = 0.925\left(\frac{(1+1.7g_Q I_{\bar{z}} Q)}{1+1.7g_v I_{\bar{z}}}\right)$$

$g_Q = 3.4$, $g_v = 3.4$ } section 6.5.8.1

$$= 0.925\left(\frac{(1+1.7(3.4)(.290)(.840))}{1+1.7(3.4)(.290)}\right)$$

$$\rightarrow G = 0.832$$

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#6 Enclosure Classification

→ enclosed per Section 6.5.9

#7 Internal pressure coefficient GC_{pi}

$GC_{pi} = +0.18$, -0.18 per section 6.5.11.1, Table 6-7

#8 External pressure coefficient, C_p per Section 6.5.11.2.1

per Fig. 6-3: North-South

$\frac{L}{B} = \frac{110}{245} = 0.45$ → windward wall $C_p = 0.8$ (use with q_z)
leeward wall $C_p = -0.5$ (use with q_h)

East West:

$\frac{L}{B} = \frac{245}{110} = 2.2$ → windward wall $C_p = 0.8$ (use with q_z)
leeward wall $C_p = -0.29$ (use with q_h) ← found using linear interpolation

#9 Velocity Pressure, q_z, q_h per Section 6.5.10, eqn 6-13

$q_z = 0.00256 K_z K_{zt} K_d V^2 I$ (lb/ft²)

North-South Direction - Main Roof:

Garden Level:

$q_{z_G} = 0.00256(0.57)(1.0)(0.85)(90^2)(1.15)$ → $q_{z_G} = 11.55$ psf

Level 1:

$q_{z_1} = 0.00256(0.5925)(1.0)(0.85)(90^2)(1.15)$ → $q_{z_1} = 12.01$ psf

Level 2:

$q_{z_2} = 0.00256(0.703)(1.0)(0.85)(90^2)(1.15)$ → $q_{z_2} = 14.25$ psf

Level 3:

$$q_{z_3} = 0.00256(0.779)(1.0)(0.85)(90^2)(1.15) \rightarrow q_{z_3} = 15.79 \text{ psf}$$

Roof:

$$q_{z_R} = 0.00256(0.87)(1.0)(0.85)(90^2)(1.15) \rightarrow q_{z_R} = 17.03 \text{ psf} = q_h$$

North-South Direction - Atrium:

Garden Level:

$$q_{z_G} = 11.55 \text{ psf}$$

Level 1:

$$q_{z_1} = 12.01 \text{ psf}$$

Level 2:

$$q_{z_2} = 14.25 \text{ psf}$$

Level 3:

$$q_{z_3} = 15.79 \text{ psf}$$

Roof:

$$q_{z_R} = 0.00256(0.89)(1.0)(0.85)(90^2)(1.15) \rightarrow q_{z_R} = 18.04 \text{ psf} = q_h$$

East-West Direction - Main Roof:

Garden Level:

$$q_{z_G} = 0.00256(0.57)(1.0)(0.85)(90^2)(1.15) \rightarrow q_{z_G} = 11.55 \text{ psf}$$

Level 1:

$$q_{z_1} = 0.00256(0.5725)(1.0)(0.85)(90^2)(1.15) \rightarrow q_{z_1} = 11.60 \text{ psf}$$

Level 2:

$$q_{z_2} = 0.00256(0.69)(1.0)(0.85)(90^2)(1.15) \rightarrow q_{z_2} = 13.99 \text{ psf}$$

Level 3:

$$q_{z_3} = 0.00256(0.77)(1.0)(0.85)(90^2)(1.15) \rightarrow q_{z_3} = 15.61 \text{ psf}$$

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Roof:

$q_{z_R} = 0.00256(0.85)(1.0)(0.85)(90^2)(1.15) \rightarrow q_{z_R} = 17.23$ psf $= q_h$

East - West Direction - Atrium:

Garden Level:

$q_{z_G} = 11.55$ psf

Level 1:

$q_{z_1} = 11.60$ psf

Level 2:

$q_{z_2} = 13.99$ psf

Level 3:

$q_{z_3} = 15.61$ psf

Roof:

$q_{z_R} = 0.00256(.878)(1.0)(0.85)(90^2)(1.15) \rightarrow q_{z_R} = 17.80$ psf $= q_h$

#10 - Design Wind Load, P per section 6.5.12.2.1

see excel pages that follow

Design Wind Load, P - per section 6.5.12.2.1

$p = qGC_p$ (psf)

North-South Direction - Main Roof:

		q	*	G	*	C_p	=	p (psf)	*	Area (sf)	=	Force (k)
WINDWARD	Garden Level	11.55	*	0.804	*	0.8	=	7.43	*	1942	=	14.4
	Level 1	12.01	*	0.804	*	0.8	=	7.72	*	2986	=	23.1
	Level 2	14.25	*	0.804	*	0.8	=	9.17	*	2986	=	27.4
	Level 3	15.79	*	0.804	*	0.8	=	10.16	*	3734	=	37.9
	Roof	17.63	*	0.804	*	0.8	=	11.34	*	2240	=	25.4
LEEWARD	Garden Level	17.63	*	0.804	*	-0.5	=	-7.09	*	1942	=	-13.8
	Level 1	17.63	*	0.804	*	-0.5	=	-7.09	*	2986	=	-21.2
	Level 2	17.63	*	0.804	*	-0.5	=	-7.09	*	2986	=	-21.2
	Level 3	17.63	*	0.804	*	-0.5	=	-7.09	*	3734	=	-26.5
	Roof	17.63	*	0.804	*	-0.5	=	-7.09	*	2240	=	-15.9

Wind Load Base Shear

	Force (k)
Garden Level	28.2
Level 1	44.2
Level 2	48.5
Level 3	64.4
Roof	41.3
Total	226.6

North-South Direction - Atrium:

		q	*	G	*	C_p	=	p (psf)	*	Area (sf)	=	Force (k)
WINDWARD	Garden Level	11.55	*	0.805	*	0.8	=	7.44	*	182	=	1.4
	Level 1	12.01	*	0.805	*	0.8	=	7.73	*	280	=	2.2
	Level 2	14.25	*	0.805	*	0.8	=	9.18	*	280	=	2.6
	Level 3	15.79	*	0.805	*	0.8	=	10.17	*	455	=	4.6
	Roof	18.04	*	0.805	*	0.8	=	11.62	*	315	=	3.7
LEEWARD	Garden Level	18.04	*	0.805	*	-0.5	=	-7.26	*	182	=	-1.3
	Level 1	18.04	*	0.805	*	-0.5	=	-7.26	*	280	=	-2.0
	Level 2	18.04	*	0.805	*	-0.5	=	-7.26	*	280	=	-2.0
	Level 3	18.04	*	0.805	*	-0.5	=	-7.26	*	455	=	-3.3
	Roof	18.04	*	0.805	*	-0.5	=	-7.26	*	315	=	-2.3

Wind Load Base Shear

	Force (k)
Garden Level	2.7
Level 1	4.2
Level 2	4.6
Level 3	7.9
Roof	5.9
Total	25.4

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East-West Direction - Main Roof:

		q	*	G	*	C_p	=	p (psf)	*	Area (sf)	=	Force (k)
WINDWARD	Garden Level	11.55	*	0.832	*	0.8	=	7.69	*	667	=	5.1
	Level 1	11.6	*	0.832	*	0.8	=	7.72	*	1333	=	10.3
	Level 2	13.99	*	0.832	*	0.8	=	9.31	*	1333	=	12.4
	Level 3	15.61	*	0.832	*	0.8	=	10.39	*	1697	=	17.6
	Roof	17.23	*	0.832	*	0.8	=	11.47	*	1030	=	11.8
LEEWARD	Garden Level	17.23	*	0.832	*	-0.29	=	-4.16	*	667	=	-2.8
	Level 1	17.23	*	0.832	*	-0.29	=	-4.16	*	1333	=	-5.5
	Level 2	17.23	*	0.832	*	-0.29	=	-4.16	*	1333	=	-5.5
	Level 3	17.23	*	0.832	*	-0.29	=	-4.16	*	1697	=	-7.1
	Roof	17.23	*	0.832	*	-0.29	=	-4.16	*	1030	=	-4.3

Wind Load Base Shear

	Force (k)
Garden Level	7.9
Level 1	15.8
Level 2	18.0
Level 3	24.7
Roof	16.1
Total	82.5

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East-West Direction - Atrium:

		q	*	G	*	C_p	=	p (psf)	*	Area (sf)	=	Force (k)
WINDWARD	Garden Level	11.55	*	0.832	*	0.8	=	7.69	*	67	=	0.5
	Level 1	11.6	*	0.832	*	0.8	=	7.72	*	133	=	1.0
	Level 2	13.99	*	0.832	*	0.8	=	9.31	*	133	=	1.2
	Level 3	15.61	*	0.832	*	0.8	=	10.39	*	217	=	2.3
	Roof	17.8	*	0.832	*	0.8	=	11.85	*	150	=	1.8
LEEWARD	Garden Level	17.8	*	0.832	*	-0.29	=	-4.29	*	67	=	-0.3
	Level 1	17.8	*	0.832	*	-0.29	=	-4.29	*	133	=	-0.6
	Level 2	17.8	*	0.832	*	-0.29	=	-4.29	*	133	=	-0.6
	Level 3	17.8	*	0.832	*	-0.29	=	-4.29	*	217	=	-0.9
	Roof	17.8	*	0.832	*	-0.29	=	-4.29	*	150	=	-0.6

Wind Load Base Shear

	Force (k)
Garden Level	0.8
Level 1	1.6
Level 2	1.8
Level 3	3.2
Roof	2.4
Total	9.8

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Roof Uplifts: - per Figure 6-3

$p = qGC_p$ (psf)

North-South Direction - Main Roof: ***h = 65*** h/L = 65/110 = 0.591

	q	*	G	*	C_p	=	p (psf)
0 to h/2	17.63	*	0.804	*	-0.925	=	-13.11
h/2 to h	17.63	*	0.804	*	-0.864	=	-12.25
h to 2h	17.63	*	0.804	*	-0.536	=	-7.60

North-South Direction - Atrium: ***h = 70*** h/L = 70/110 = 0.636

	q	*	G	*	C_p	=	p (psf)
0 to h/2	18.04	*	0.805	*	-0.988	=	-14.35
h/2 to h	18.04	*	0.805	*	-0.846	=	-12.29

East-West Direction - Main Roof: ***h = 60*** h/L = 60/245 = .245

	q	*	G	*	C_p	=	p (psf)
0 to h/2	17.23	*	0.832	*	-0.9	=	-12.90
h/2 to h	17.23	*	0.832	*	-0.9	=	-12.90
h to 2h	17.23	*	0.832	*	-0.5	=	-7.17
>2h	17.23	*	0.832	*	-0.3	=	-4.30

East-West Direction - Atrium: ***h = 67*** h/L = 67/245 = .273

	q	*	G	*	C_p	=	p (psf)
h/2 to h	17.8	*	0.832	*	-0.9	=	-13.33
h to 2h	17.8	*	0.832	*	-0.5	=	-7.40

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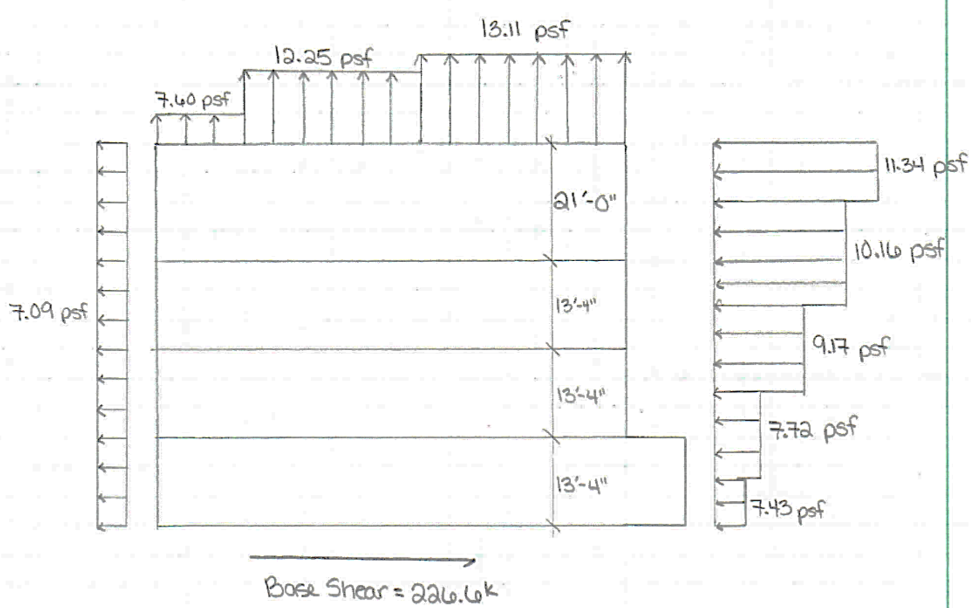
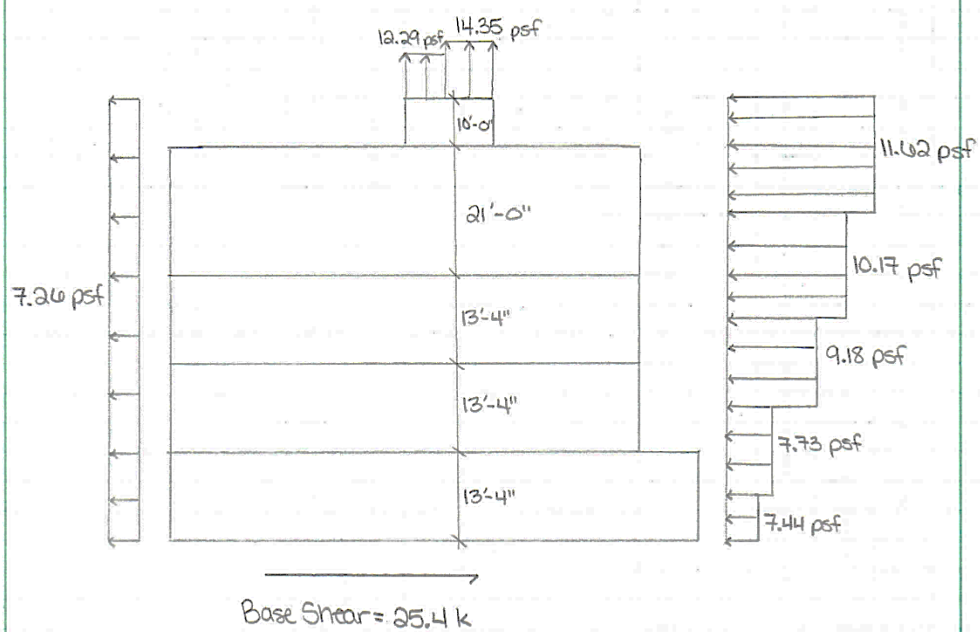
North-South Direction - Main Roof:



North-South Direction- Atrium:



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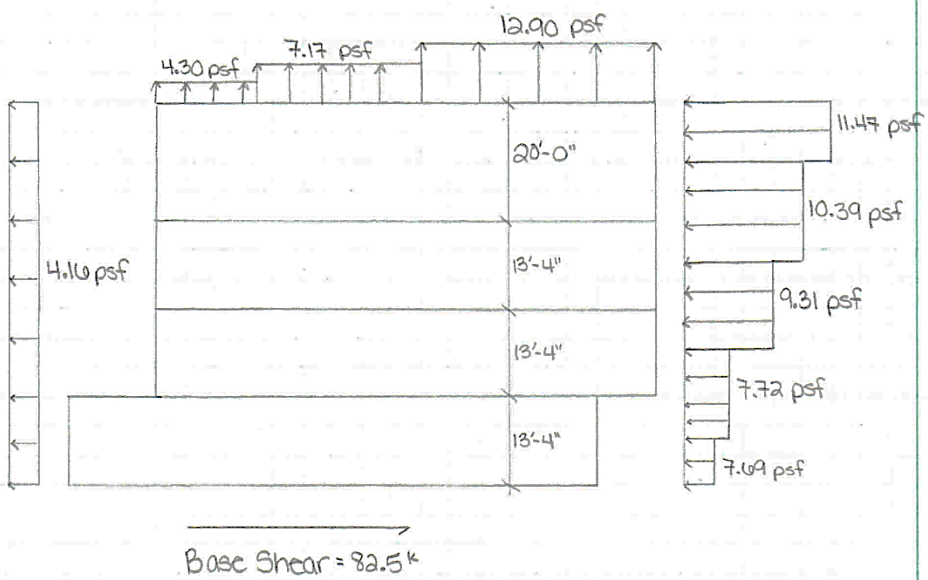
East West Direction - Main Roof



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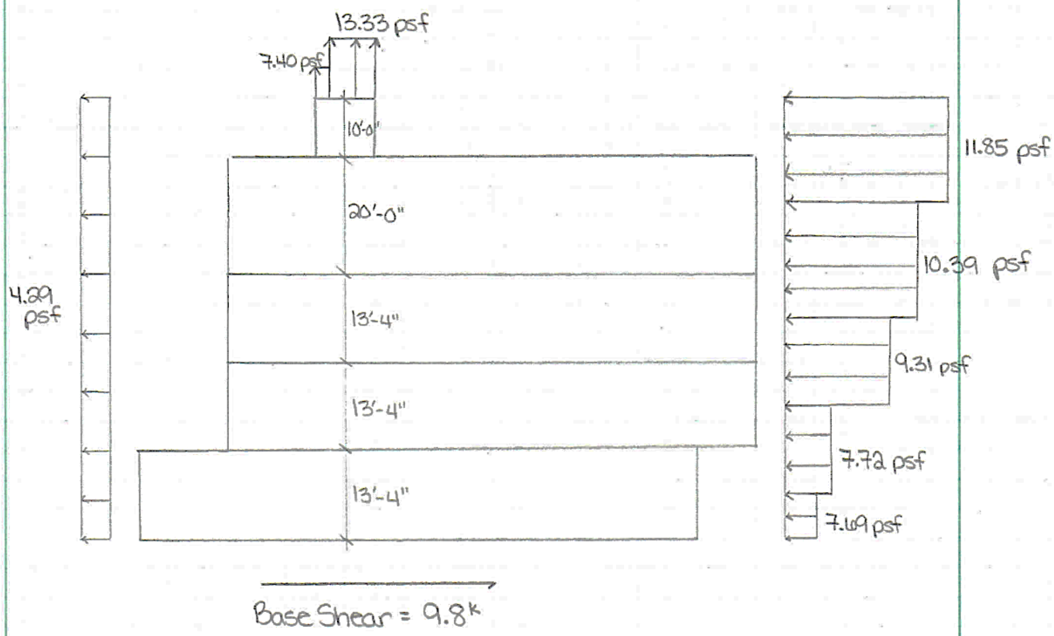
East West Direction - Atrium:



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#1 Exempt?

Occupancy Category : III → per Table 9.1.3
Seismic Use Group = II

Site Class : B

S_s = 18.7 %g → 0.187 g
↳ per Figure 9.4.1.1 (a)

S_1 = 6.3 %g → 0.063 g > 0.04g → not exempt
↳ per Figure 9.4.1.1 (b)

#2 Occupancy Importance Factor
I = 1.25 → per Table 9.1.4

#3 Adjust for site class: → per Section 9.4.1.2.4

$S_{MS} = F_a S_s$ $F_a = 1.0$ (Table 9.4.1.2.4a)

$S_{MS} = (1.0)(0.187)$ → $S_{MS} = 0.187$

$S_{M1} = F_v S_1$ $F_v = 1.0$ (Table 9.4.1.2.4b)

$S_{M1} = (1.0)(0.063)$ → $S_{M1} = 0.063$

#4 Spectral Response Acceleration Parameters: (Section 9.4.1.2.5)

$S_{DS} = \frac{2}{3} S_{MS}$

$S_{DS} = \frac{2}{3}(0.187)$ → $S_{DS} = 0.125$

$S_{D1} = \frac{2}{3} S_{M1}$

$S_{D1} = \frac{2}{3}(0.063)$ → $S_{D1} = 0.042$

#5 Seismic Design Category (Table 9.4.2.1a)

Seismic Design Category A

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#6 Select Procedure:

Due to the PRWC classifying as seismic design category A, per section 9.5.2.5.1:

the building "shall be analyzed for minimum lateral forces given by eqn. 9.5.2.5.1, applied independently, in each of two orthogonal directions"

eqn 9.5.2.5.1 $F_x = 0.01\ W_x$

per Table 9.5.2.2

Structural Steel Systems Not Specifically Detailed for Seismic Resistance

R = 3

	Area (SF)	W (psf)	Wx (K)
Level 1			
typ. Floor	14,682	92.5	1,358
Green Roof	3,157	171	540
Deck	3,942	124	489
Level 2			
typ. Floor	15,257	92.5	1,412
Level 3			
typ. Floor	12,785	92.5	1,183
Green Roof	2,899	171	496
Roof			
typ Roof	15,936	48.2	769
Atrium			
typ Roof	204	48.2	10

* W - per section 9.5.3.2 is the dead load only
- I will use the previously calculated typical floor bay loading, typical roof bay, green roof, and deck area loadings.

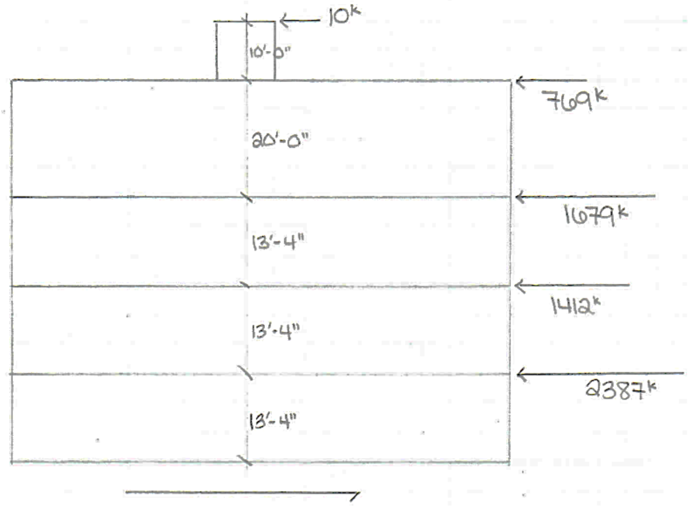
$W_1 = 1358 + 540 + 489 \rightarrow W_1 = 2387^k$

$W_2 = 1412^k$

$W_3 = 1183 + 496 \rightarrow W_3 = 1679^k$

$W_R = 769^k$ $W_{R\,atrium} = 10^k$

North-South and East-West Seismic Forces:



Base Shear = 6257^k